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PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 9 (5): 985-990, 2006
ISSN 1028-8880

Temporal and Spatial Variability in Streamwater Quality in a Catchment Affected by Waste-waters

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Abstract: The stream water quality of the Yalfan catchment of Iran has been studied intensively because of high organic pollutants loading to the Ekbatan Dam Lake. The influences of village's wastewaters on the streamwater quality within the catchment were examined. The surface water has been contaminated with the faecal materials of man or animals. These pollutants could be contributed independently or in combination, to the very high levels in bacterial counts that were observed at this sampling site. All data include total and faecal coliforms counts, turbidity, pH, DO and COD at 11 different sites of the Yalfan River and demonstrate seasonal patterns for the period April 2003 to September 2004, which were divided on the dry seasons rainy seasons. The results indict that quality of the Yalfan River waters is generally better in the rainy seasons. But, the quantity of the wastes from human sources during the dry seasons is not very different to the rainy seasons. The total period analysis sheds no light on any significant trends in water quality over time within the year. The catchment situation's resulting an important increasing of the COD, total coliforms and faecal coliforms at the end of Yalfan River direction that are in average 5, 10 and 13 times of upstream of the river, respectively. Conversely, dissolved oxygen level decreased along the river toward the end of direction. The averages of the total and faecal coliforms counts and so the COD throughout the sites were generally high of 1396 and 1185 MPN 100 mL^{-1} and 1209 mg L^{-1}, respectively. This study generated some essential information of the Yalfan River pollutant sites that cause the microbiological contamination of the river as an important resource of Hamadan drinking water.

Key words: Streamwater quality, total coliforms, faecal coliforms

INTRODUCTION

In the study of a natural ecosystem, many variables simultaneously change on time and space with little opportunity to control them all, systematically or otherwise (Jonnalagadda and Mhere, 2001). By measuring as many parameters as possible that define the system, it may be possible to understand their interactions and to assess the sustainability of the environment (Hopke, 1985).

The drinking water quality is normally determined by monitoring microbial presence, especially coliform bacteria and physico-chemical substances (Gray, 1994; Ford and Colwell, 1996; Reisenhofer, 1998; Boualam *et al*., 2002). After the report of the World Health Organization (WHO, 1992) nearly half of the population in developing countries suffers from health problems associated with lack of drinking water or the presence of microbiologically contaminated water. Many rivers and streams in these countries are heavily polluted due to anthropogenic activities, such as industrial and sewage discharges (Mathuthu *et al*., 1993; Nriagu, 1994; Jonnalagadda and Nenzou, 1996; Geldreich and LeChevallier, 1999).

There are many sources of contamination of drinking water. Broadly, they can be divided in two categories: I) contaminants that are in ground and surface water of the drinking water sources and ii) contaminants formed during the treatment and distribution of drinking water. Contaminants in ground and surface water will range from natural substances leaching from soil, runoff from agricultural activities, controlled discharge from sewage treatment works and industrial plants (Bezuidenhout *et al*., 2002) and uncontrolled discharges or leakage from landfill sites and from chemical accidents or disasters.

Hardness, salinity, chlorides, pH, temperature, turbidity and dissolved oxygen are some physico-chemical properties determine stream conditions. These parameters that are parts of the overall water quality testing could be affected by Hydro-Meteorological events, geological specifications of area and human pollution.

Occurrence of coliforms bacteria in streamwater is an important indicator of microbiological water contamination. Although these bacteria are not necessarily dangerous to humans, their presence in stream indicates that the water is contaminated with faecal waste from warm-blood animals that increase a potential risk to human health. The faecal coliforms count is a more reliable indicator of the sanitary quality of water because some coliforms generations and species those are faecal or non-faecal origin (Alonso *et al.*, 1999).

Yalfan catchment that is the basin of Ekbatan Dam collects the surface water of all streams through the area. The catchment contains 9 villages located near the streams course that directly drain the used and wastewater. These situations cause the microbiological contamination that risk public health of Hamadan city. The overall aim of this study is microbiological quality assessments of Yalfan River as a main resource of Hamadan drinking water.

MATERIALS AND METHODS

Site description: The study site is Yalfan catchment situated about 21 km south east of Hamadan, in western Iran, at 33°45′ and 47°35′. The site is mountainous of a drainage basin area approximately 213 km^2. The average altitude of site is 2522 m. The climate of region is cold semi-arid based on the Emberger classification. The average annual rainfall of study area is 370 mm. In general, low flow at this site occurred in the end of summer and fall. More than 9 urban communities sited in the Yalfan catchment are: Tokmedash, Shams-Abad, Varkane, Arzanfood, Ali-Abad, Yalfan, Eberoo, Enjelas and Symin (Fig. 1).

The consumption uses of these villages are directly dependent on the main stream for all water uses including to drinking, washing and agricultural activities. In some cases, treated water is unavailable or the treatment process is not standard and sufficient. The Ekbatan Dam has been constructed over the main river of basin in 1965 to water supply development of Hamadan city, situated behind of Yalfan catchment.

All the rural wastewaters and sewages are directly drain by phisiographic network of the catchment. The streams network is the main pollution source of the catchment and the lake of Ekbatan Dam. Because of this situation, faecal coliforms is the most frequently stream impairment on the Yalfan catchment. Through the rivers flows, especially during the rainy periods, contaminate microorganisms can reach to the lake of dame that causes a potential public-health risk of infection.

Sampling and measurement: In order to understand the controls on water quality of the Ekbatan Dam Lake, a test program was performed on a regular basis from April 2003 through September 2004 at 11 locations along the main river of Yalfan catchment. Sampling sites were selected just before and after of the villages which sited across the longitudinal section of main river of the catchment. The samples were done in the sterile 300 cc glass bottles. They were immediately stored at 4°C in a dark Ice-bag and transported to laboratory for testing and analysis within 3-5 h of collection.

Fig. 1: Map of Ekbatab Dam catchment showing the sampling sites

Total samples for either the dry seasons or rainy seasons were 85. Temperature, pH, concentration of dissolved oxygen (DO), chemical oxygen demand (COD), turbidity, total coliforms and faecal coliforms of the samples were analyses. The laboratory analyses were carried out according to generally accepted basic laboratory procedures (Standard Methods, 1998). To calculate coliform density (total or faecal coliforms), the Most Probable Number (MPN) was determined. The MPN Index/100 mL (values) at 95% confidence limits, for the used series of decimal dilution was determined based on the Standard Methods recording tables.

Statistical analysis: Statistical parameters of total coliforms and faecal coliforms, COD, DO, turbidity and pH analyses data were used to present the values of these water quality characteristics. Pearson's correlation coefficient (r) was used to show correlation between the microbiological data using the SPSS software. The Student's t-test was used to determine the statistical significance. Probability was set at $p<0.05$.

RESULTS

Temporal variability of water quality: The five drinking water quality parameters were determined from 11 points along the river during experimental period. A temporal analyzed was examined using a seasonal classification of data. All data were divided by two categories, based on the period of sampling: I) dry seasons (summer and fall) and ii) rainy seasons (winter and spring). Table 1 and 2 summarize the statistical characteristics of the various parameters monitored during the dry and rainy periods, respectively.

Total coliforms and faecal coliforms: The results show a non-significant relevant between the total coliforms measured during the dry and rainy periods. The same results were achieved for faecal coliforms. The average of total coliforms measured during the rainy seasons (1402 MPN 100 mL^{-1}), because of more leaching, are slightly higher than dry seasons (1359 MPN 100 mL^{-1}). Conversely the faecal coliforms means measured during the rainy seasons (1223 MPN 100 mL^{-1}) are slightly lower than dry seasons (1125 MPN 100 mL^{-1}).

COD, DO and pH: The Chemical oxygen demand value measured of dry seasons (1337 mg L^{-1}) is higher than the value of rainy seasons (1050 mg L^{-1}). The dissolved oxygen value measured during the dry seasons (3.8 mg L^{-1}) is also lower than the value of rainy seasons (4.4 mg L^{-1}). The pH values measured during the dry and rainy seasons are nearly similar, which are 7.2 and 7.4, respectively.

Table 1: The statistical characteristics of the samples collected during dry seasons

Statistical analysis	Total coliforms (MPN 100 mL^{-1})	Faecal coliforms (MPN 100 mL^{-1})	DO (mg L^{-1})	COD (mg L^{-1})	pH	Turbidity (NTU)
Mean	1359.0	1223.0	3.8	1337.0	7.4	4.21
Min.	180.0	110.0	2.4	125.0	5.6	0.89
Max.	5320.0	5320.0	7.3	4800.0	8.1	10.70
SD	1186.0	1199.0	1.2	969.0	0.5	3.24
CV	87.0	98.0	31.0	72.4	7.2	77.00

Table 2: The statistical characteristics of the samples collected during rainy seasons

Statistical analysis	Total coliforms (MPN 100 mL^{-1})	Faecal coliforms (MPN 100 mL^{-1})	DO (mg L^{-1})	COD (mg L^{-1})	pH	Turbidity (NTU)
Mean	1402.0	1125.0	4.4	1050.0	7.2	21.3
Min.	110.0	90.0	2.9	310.0	6.4	5.1
Max.	5320.0	5320.0	7.3	3100.0	7.6	256.0
SD	1219.0	1113.0	1.3	688.0	0.2	25.0
CV	87.0	99.0	29.0	65.5	3.0	117.0

Table 3: The mean value of the samples from different points of catchment

Sampling sites	Total coliforms (MPN 100 mL^{-1})	Faecal coliforms (MPN 100 mL^{-1})	DO (mg L^{-1})	COD (mg L^{-1})	pH
Tokmedash U.	385	256	4.5	509	7.1
Tokmedash D.	575	491	4.4	759	7.3
Arzanfood U.	599	555	4.4	751	7.4
Arzanfood D.	960	819	4.0	1027	6.9
Ali-Abad U.	1109	824	3.9	936	7.3
Ali-Abad D.	1269	1128	3.9	1077	7.4
Yalfan U.	1495	1138	4.2	1299	7.4
Yalfan D.	3880	3445	3.8	2597	7.5
Ekbatan Lake U.	2303	2165	3.9	1964	7.4
Ekbatan Lake D.	1385	1030	3.9	1168	7.2
Water Refinery D.	0	0	4.9	407	7.1

U.; Upstream, D.; Downstream

Spatial analyses of water quality: In order to compare the overall statistics of selected water quality parameters from site to site, collected data at the 11 sites were analysed. The averages of the total coliforms, faecal coliforms and COD values observed at the sampling sites (expected the Water Refinery data) are 1396 and 1185 MPN 100 mL^{-1} and 1209 mg L^{-1}, respectively (Table 3). The results suggest a significant difference between upstream and downstream of each village. The difference between total coliforms, faecal coliforms and COD values measured at upstream and downstream points of Tokmedash, Arzanfood and Yalfan were significant ($p<0.05$).

Spatial water quality trends: To spatial variability verification of water quality properties, all values of the measured parameter from the most upstream site (at before Tokmedash) to the most downstream site (near Ekbatan Dam Lake) were compared. The COD, total coliforms and faecal coliforms values increase significantly toward the outlet of basin. The highest values of all parameters were observed at downstream of Yalfan. At downstream of the Yalfan COD, total coliforms and faecal coliforms were in

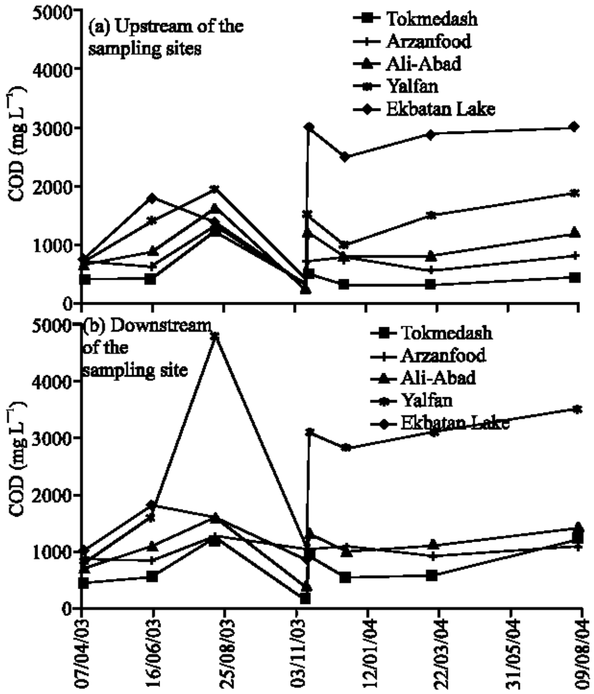

Fig. 2: Seasonal variations in the COD measured at upstream (a) and downstream (b) of villages of the catchment

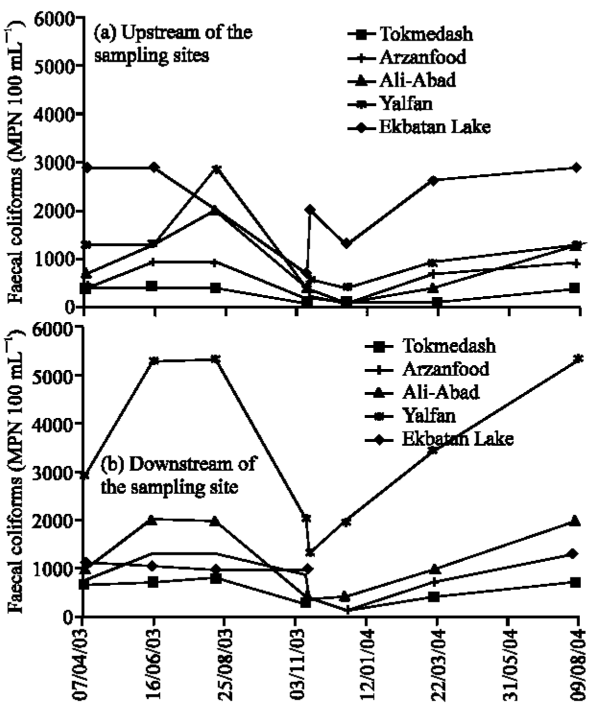

Fig. 3: Seasonal variations in the faecal coliforms measured at upstream (a) and downstream (b) of villages of the catchment

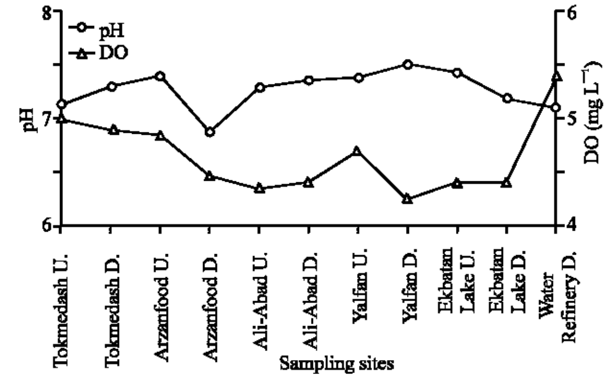

Fig. 4: Seasonal variations in the DO and pH measured at Yalfan catchment

average 5, 10 and 13 times of the upstream Tokmedash, respectively. After this point, because of none at all of villages or urban sites, the values of these parameters decrease again.

The role of each the village of the COD and feacal coliforms of the river water are shown by the Fig. 2 and 3. Figure 2 and 3 clearly show the contamination role of the villages in water quality of Yalfan River. The Pearson correlation coefficient calculated between COD on the one hand and total colliforms and faecal colliforms on other are r = 0.98 and r = 0.99 (both of them are at 0.05 level of significant), respectively. The Fig. 4 also suggest that DO value of the water flow decrease (about 80%) between the upstream (before Tokmedash) and downstream (near to the Ekbatan Dam Lake) of the basin. It increases again after passing through the drinking water refinery system of Ekbatan Dam.

DISCUSSION

At the Yalfan catchment, with increasing demands on water resources and contamination from agricultural waste and human activities, the potential outbreaks of water-borne diseases continue to grow. Insufficient data on the population of human pathogens and indicator microorganisms for the catchment motivated this study. The intention of this study was to generate more extensive microbial situation for the main river of this basin. All results include total and faecal coliforms counts, turbidity, pH, DO and COD at 11 different sites of the Yalfan River and demonstrate seasonal patterns for the period April 2003 to September 2004.

The results indict that the quality of the Yalfan River waters is generally better in the rainy seasons. Turbidity is the only parameter, which is worse in the rainy seasons due to increased erosion in the basin. But, the quantity of the wastes from human sources during the dry seasons is not very different to the rainy seasons. These results are similar as the other researches (Palupi *et al*., 1995; Jagals, 1995). The total period analysis sheds no light on any significant trends in water quality over time within the year.

Faecal coliforms are chosen as an indicator for the pollution of domestic wastewater of area (Sherer *et al*., 1992; Harwood *et al*., 2000; Sayah *et al*., 2005). The means total and faecal coliforms counts (Table 3) throughout the study period were generally very high and about those observed in other studies (Byamukama *et al*., 2000; Goni-Urriza *et al*., 2000). The bacteriological quality of the Yalfan River water posed an increased risk of infectious disease transmission to the communities that were dependent on the river for household and other purposes.

A perusal of the data shows the water pollution increases as the river descends from the slopes of highlands to the plain. Further, the results that are illustrated in the Table 3 depicting the spatial variations of selected parameters at the sampling sites. It shows clearly the pollution rate increasing from the upper to lower basin. At some locations especially after the Yalfan village or the intake of the Ekbatan Dam Lake, faecal coliforms concentration remains higher than 3400 MPN 100 mL^{-1}. This observation indicates a high health risk for direct water use from the river that could be from the high counts of faecal coliforms and low dissolved oxygen concentration.

Most applications of COD determine the amount of organic pollutants found in lakes and rivers, making COD a useful measure of water quality. The Pearson correlation coefficient calculated between the COD and colliforms counts consist the important relation of COD and organic pollutants. COD increases about 5 times through water direction toward end of basin. As dissolved oxygen levels in water drop below 5 mg L^{-1}, aquatic life is put under stress. After the majority of water standards, DO concentrations should not be below this value (Alabaster, 1982; EPA, 1986). The result suggests that at the some locations along the river DO was ranged below from its standard value.

pH of the aquatic systems is an important indicator of water quality and the extent pollution in the watershed areas. Unpolluted streams normally show a near neutral or slightly alkaline pH (Sanchez-Maranon *et al*., 2002). Most of the water samples had a pH between 7 and 8. In average, downstream of the Arzanfood (6.9) and Yalfan (7.5) have the higher and lower pH of the water, respectively. pH increasing at the middle direction of river (near the Yalfan village) could be due to very slightly alkaline waters from the Yalfan River, which are concentrated on the river flow. This increased pH caused reduction of *Escherichia coli* when grown in association with algae (Parhad and Rao, 1974). Figure 4 shows the spatial variation in the pH values at the 11 sites. pH values lower than 7 at Arzanfood downstream (lowest 6.9) were due to the leachates and rain-runoff waters from the silica sand dispositions holes. The silica sand is exposed at surface or occurs beneath thin overburden that largely explored around Arzanfood by the villagers for a glass factory of region.

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